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IGU Commission on Frost Action Environments
IPA Working Group on Periglacial Environments

EXCURSION GUIDE

Symposium periglacial environments in relation to climatic change
Maastricht / Amsterdam, 3rd - 6th May 1991

vrije Universiteit *amsterdam*

EXCURSION SITE 8

EARLY PLEISTOCENE PERIGLACIAL ENVIRONMENTS IN BEERSE

K. Kasse

Introduction

Excursion site Beerse is situated in northern Belgium, approximately 30 km east of Antwerp and 9 km west of Turnhout (fig. 8.1). The undulating coversand landscape is 25 to 30 m above sea level.

In this region Early-Pleistocene deposits occur close to the surface. They dip towards the North Sea basin, where the base of the Quaternary deposits is found up to 900 m below the surface, which illustrates the rapid subsidence of the North Sea basin during the Quaternary (Zagwijn, 1989). South of the excursion site the Early-Pleistocene units have been eroded, because of uplift of Belgium. The Early-Pleistocene units are covered by a thin layer (1-2 m) of mostly eolian sand from the Weichselian period. Late Early- and Middle-Pleistocene deposits are missing because of erosion, which is expressed at the excursion site by a gravel-bed on top of the Early-Pleistocene sediments (see excursion site 9: Meerle).

Due to the Middle- and Late-Pleistocene uplift and erosion the so-called Campine microcuesta developed, which consists of Early-Pleistocene compact clay-beds (De Ploey, 1961). The cuesta slope dips to the north (0.1%), while the steeper cuesta front dips south (0.2-0.5%) towards the Nete river, which flows to the west and discharges into the Scheldt near Antwerp. The excursion site is situated on top of the microcuesta, where the Early-Pleistocene clay-beds are exploited by brick-factories.

During the Early-Pleistocene tidal, fluvial and eolian deposition occurred in the excursion area, depending on climate and climate related sea level changes. The Early-Pleistocene sequence consists from bottom to top of three members: Rijkevorsel, Beerse and Turnhout Member, which together form the Campine Clay and Sand Formation (Paepe & Vanhoorne, 1976). These Belgian lithostratigraphic units have been correlated with the Tegelen Formation in The Netherlands (Zagwijn & Van Staalduinen, 1975; Kasse, 1988, 1990). In this excursion paper special attention is given to the sedimentological, ecological and climatological aspects of the Beerse Member.

The "Beersien" unit was introduced by Dricot (1961). He described a sand-unit, between two clay-units, which was characterized by a stable, so-called B-Limburg, heavy mineral association. He interpreted the "Beersien" unit on granulometric and palynological grounds as an eolian deposit formed in an arctic climate during the Eburonian or Menapian glacial stages. Later Paepe & Vanhoorne (1970) correlated this unit with the Eburonian stage. Recently, Kasse (1988, 1990) stated that the Beerse Member was formed during an intra-Tiglian cold phase, probably the Tiglian C4 period. This finding sheds new light on the climatic evolution of the Quaternary, since it indicates that periglacial conditions and permafrost already occurred during the early Early-Pleistocene (Vandenberghe & Kasse, 1989).

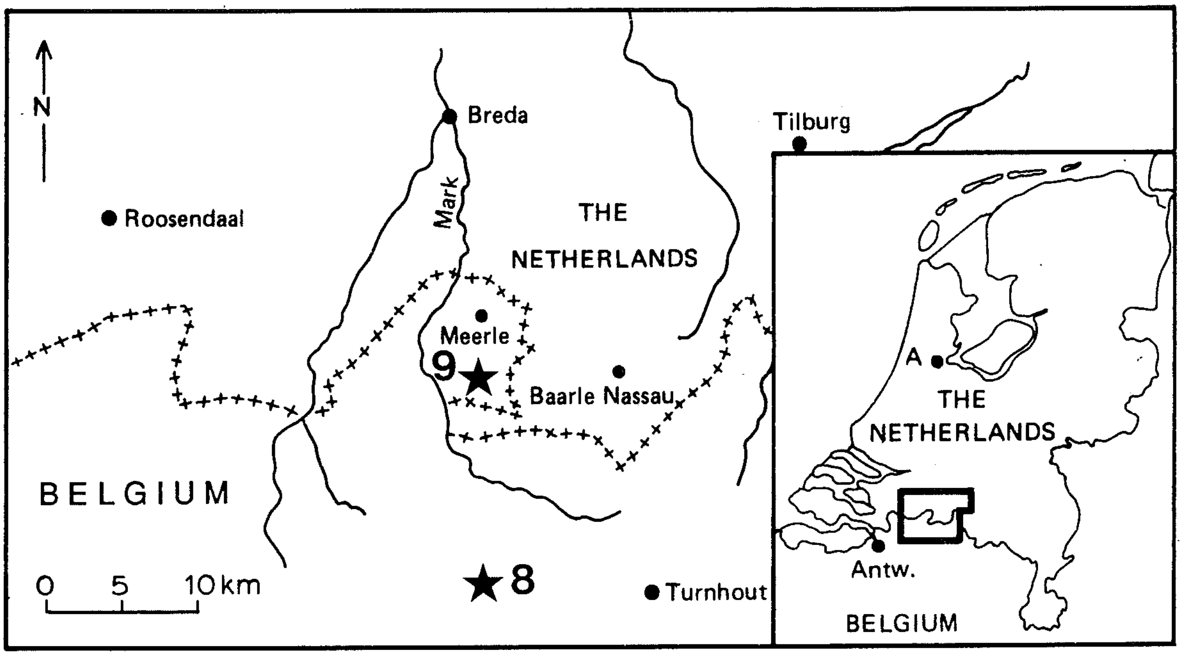


Fig. 8.1 Location map of excursion site 8 (see also fig. 6.2 for location).

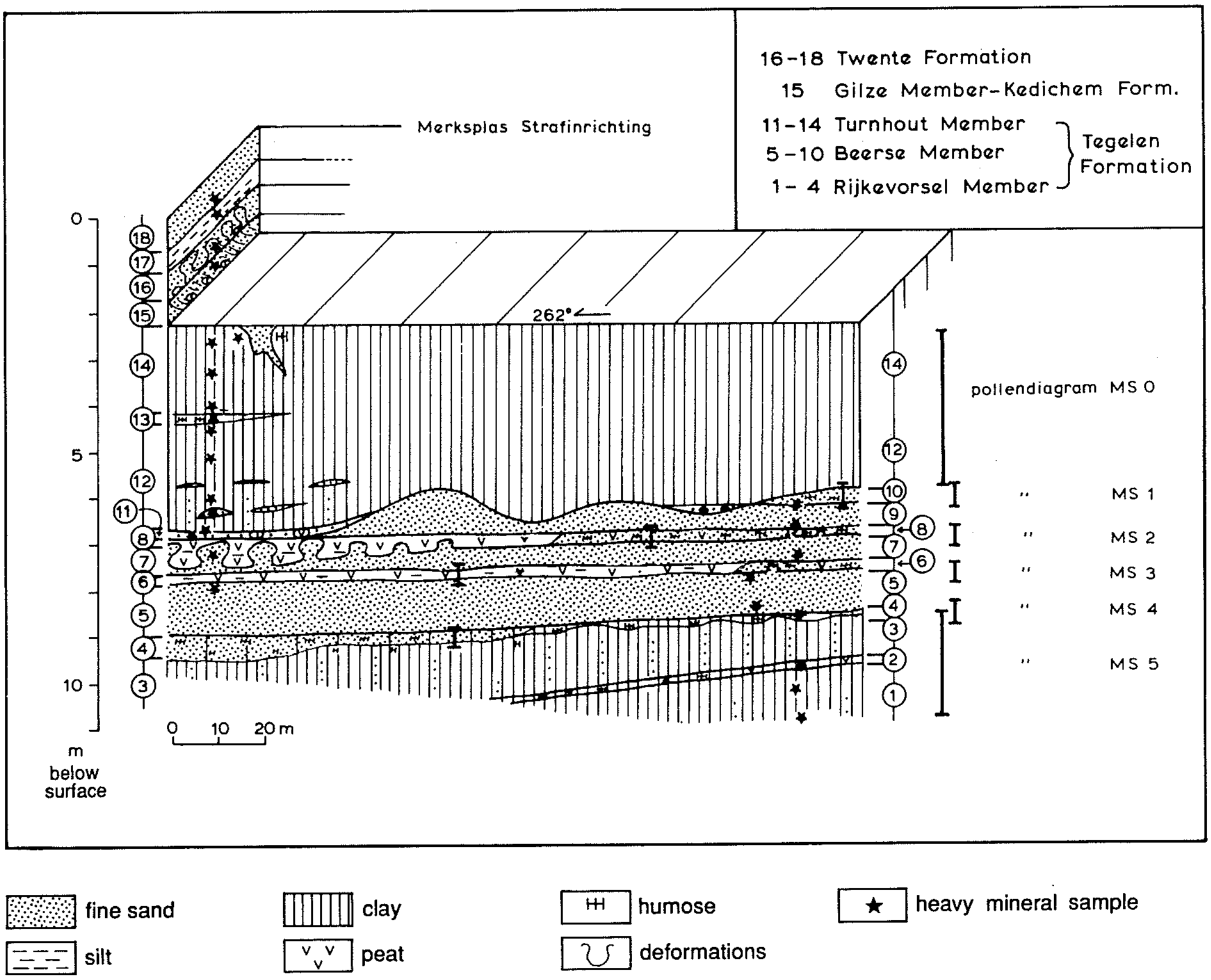


Fig. 8.2 Lithology of exposure Merksplas.

Lithostratigraphy and provenance

The lithostratigraphic upbuilding of the excursion site is illustrated in fig. 8.2. Exposure Merksplas was located 3.5 km north of Beerse, but reveals a comparable stratigraphic sequence.
At the base of the pit a bluish gray clay-bed occurs, which forms the top of the Rijkevorsel Member. This member is characterized by a fining-upward sequence, which formed in an inshore tidal (estuarine) environment. The crumbly clay (by soil ripening) and peaty beds in the upper part reflect the final silting and freshening of the estuarine environment.

Garnet, epidote and hornblende are the dominant heavy minerals in the Rijkevorsel Member, which point to a Rhine supply (Zonneveld, 1948). South of Merksplas the garnet, epidote and hornblende content decreases and zircon, rutile and tourmaline become more important (fig. 8.3). This change in heavy mineral composition is attributed to an additional supply from the south by the Scheldt and other Belgian rivers, discharging their sediment at the southern margin of the North Sea basin.

The Rijkevorsel Member is concordantly overlain by the Beerse Member. The fluvial and eolian fine sands of the Beerse Member are characterized by the presence of three or four, often strongly deformed humic soils or peat-beds (fig. 8.2). The Beerse Member has been preserved along the southern margin of the North Sea basin only. Basinwards, this unit was eroded during the formation of the overlying Turnhout Member.

In contrast to the Rijkevorsel and Turnhout Members, the fine sands of the Beerse Member are dominated by stable heavy minerals (zircon, rutile, staurolite, andalusite, kyanite and tourmaline) (fig. 8.3). This association reflects a strong increase of sediment supplied by the rivers from Central Belgium (Kasse, 1990). In theory, the expansion of the Belgian rivers to the north, over the previously formed estuarine deposits of the Rijkevorsel Member, can be explained by normal silting of the basin. The progradation of the coast would lead to an off-lap sequence with continental, fluvial and eolian deposits overlying inshore tidal and marine sediments. However, according to the palynological results, this vertical facies change is accompanied by a change in pollen composition, from temperate type pollen assemblages in the Rijkevorsel Member to cool/cold type pollen assemblages in the Beerse Member (fig. 8.5). Therefore, it is concluded that the change in facies from the Rijkevorsel Member into the Beerse Member was not caused by silting only. The deterioration of the climate probably resulted in a significant sea level drop, which triggered the expansion of the Central Belgian rivers to the north (Kasse, 1988, 1990).

The Beerse Member is overlain erosively by the tidal channels of the Turnhout Member. Therefore, the thickness and number of soils of the Beerse Member vary considerably over a short distance (see fig. 8.2). The base of the Turnhout Member consists of fine to medium sand, locally with large peat-clasts, eroded from peat-beds in the Beerse Member. A thick, crumbly, greenish gray clay-bed, locally with an intercalated peaty bed, is found in the upper part of the Turnhout Member. The up to 5 m thick fining-upward sequence is explained by lateral migration of tidal channels and vertical accretion in the inshore tidal (estuarine) environment.

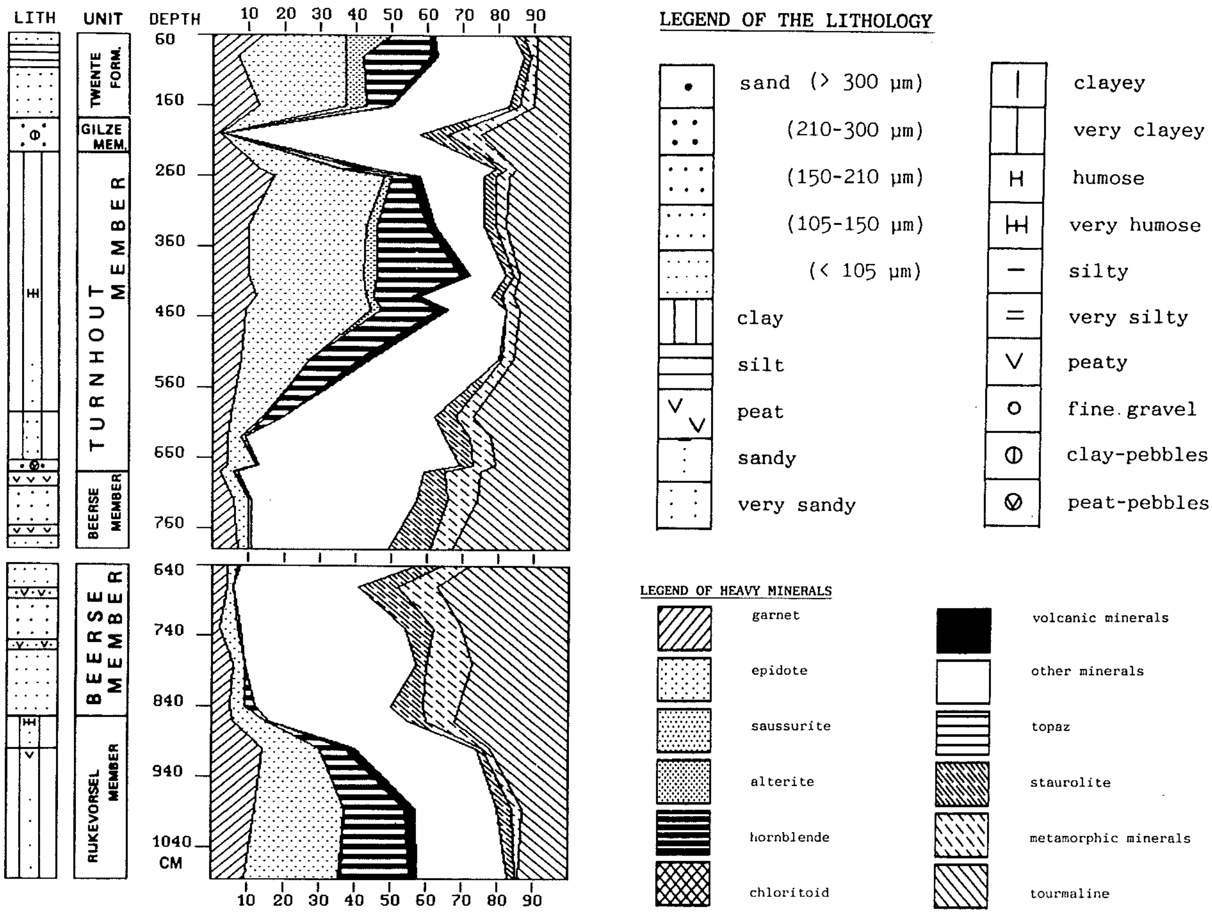


Fig. 8.3 Heavy mineral diagram of exposure Merksplas (depth in cm below the surface).

The heavy mineral composition of the Turnhout Member is well comparable with the one of the Rijkevorsel Member (fig. 8.3). The mixture of relatively unstable minerals (garnet, epidote, hornblende) and stable minerals (zircon, rutile, metamorphic minerals, tourmaline) points to the interfingering of two sediment petrographical provinces. The Rhine flowed through the Central Graben to the northwest (Zagwijn, 1989). Its sediments, dominated by garnet, epidote and hornblende, were redistributed in the Southern North Sea basin by tidal processes. Along the margin of the basin an admixture occurred with sediments dominated by stable heavy minerals, which were supplied by the rivers from Central Belgium (Kasse, 1990).

The lithology and sediment petrography of the Rijkevorsel and Turnhout Members indicate that both units are part of the Tegelen Formation in The Netherlands (Zagwijn & Van Staalduinen, 1975; Kasse, 1988). The presence of the waterfern Azolla tegeliensis in both units proves their Tiglian age. Therefore, the intercalated Beerse Member is part of the Tegelen Formation and was formed during the Tiglian as well. This age contrasts previous ideas of Paepe and Vanhoorne (1970), who correlated the Rijkevorsel, Beerse and Turnhout Members with the Tiglian, Eburonian and Waalian respectively.

On top of the Turnhout Member a thin fluvial sand-unit is found locally, which is dominated by stable heavy minerals (fig. 8.2 and 8.3: Gilze Member, Kedichem Formation). This unit is thin on the Campine microcuesta, because of Middle- and Late-Pleistocene erosion, but it thickens rapidly to the north. Pollen-analytical investigations of peat-beds in the Gilze Member indicate an Eburonian, Waalian and Menapian age (Kasse, 1988).

The top of the Turnhout and Gilze Members is heavily deformed by ice-wedge casts and involutions, which form a polygonal pattern. Similar periglacial structures will be discussed in more detail at excursion site 9: Meerle.

A gravel-bed separates the Early-Pleistocene Gilze and Turnhout Members from the Late-Pleistocene Twente Formation. It reflects the Middle- and Late-Pleistocene erosion, by which the Campine microcuesta developed. In this erosional phase sand was removed and the gravel was concentrated in a gravel lag deposit.

The upper silt- and fine sand-beds (2 m) of the sedimentary sequence are part of the Weichselian Twente Formation (fig. 8.2). The morphological position of these beds on top of the microcuesta indicates an eolian origin. The locally humose character of the silt-bed is explained by (eolian) deposition on a very wet surface or by deposition in shallow, stagnant pools, which could develop on the (cryoturbated) almost impermeable clayey subsoil of the Turnhout Member.

The heavy mineral composition of the Twente Formation (fig. 8.3) is very characteristic for the Weichselian eolian deposits in the southern Netherlands and northern Belgium. The mixed assemblage of stable and unstable minerals is more or less independent from the underlying Early-Pleistocene substratum. It points to a regional sediment supply and mixing of sediments from different petrographical provinces (Vandenberghe & Krook, 1985).

Depositional environment

- Sedimentary structures:

The Beerse Member consists of fine sand (105-210 μm) with several humic or peaty soil horizons and periglacial structures (fig. 8.2). The bedding types in the Early-Pleistocene Beerse Member resemble those of the Late-Pleistocene coversands, as described by Schwan (1988).

Discontinuous and continuous wavy bedding are dominant. Small-scale cross-lamination, low-angle cross-bedding and horizontal parallel lamination occur less frequently (fig. 8.4). The wavy bedding is explained by adhesion of windblown sand in plane beds or small adhesion ripples on a moist to wet surface. Local reworking of this eolian sediment by surficial runoff formed some small-scale cross-lamination (fig. 8.4: between 70-80 cm). The horizontal parallel lamination (top fig. 8.4) is interpreted as eolian deposition in plane beds or by flat wind ripples on a dry surface. The alternations in the upper part of the lacquer peel of wavy adhesion ripple bedding and eolian planebed lamination indicate subtle changes in soil moisture content. A local groundwater table at the surface resulted in adhesion ripple formation, while a groundwater table slightly below the surface resulted in planebed deposition.

The Beerse Member shows an overall upward decrease of current flow and the effects of a high soil moisture content (drying-upward sequence). In the lower part more small-scale current ripple cross-lamination and shallow channel fill cross-bedding are found. Towards the top more wet eolian adhesion ripple bedding and dry eolian plane bedding occur. A comparable drying-up sequence is locally found on a smaller scale within one sand-unit between two soils.

It is unknown whether this upward decrease in moisture in the sequence is due to the sedimentation itself or that climatological changes took place during the formation of the Beerse Member. The first hypothesis, being the most simple one, is favoured here. The mere deposition of a sand-bed on an impermeable clayey subsoil will improve the vertical drainage, because of the larger water storing capacity of the sand-bed. The thicker the sandy unit becomes, the larger the water storing capacity will be. Surficial water flow is less likely to occur, if it is assumed that precipitation and evapotranspiration remained constant.

- Geomorphology:

The eolian interpretation of the Beerse Member is supported by the geomorphological position of the deposits. The sand-units and peat-beds/soils occur in a stacked sequence (fig. 8.2). The humose, sandy soils are present above each other in the eastern part of the exposure (fig. 8.2). The peaty beds, formed in low, wet conditions, occur in the western part. The sand-units form parallel sand-sheets with uniform thickness between the soils/peaty beds. If the deposition of the Beerse Member had taken place by predominantly fluvial processes, then local erosion of the higher topographical elements (humose soils) and aggradation of the depressions should be expected. However, the topography of the underlying Rijkevorsel Member persisted in the successive phases of the Beerse Member and erosion did not occur in the receiving site. Such a stacked sequence can be explained by deposition in eolian sand sheets (Ruegg, 1983; Schwan, 1988; Kocurek & Nielson, 1986).

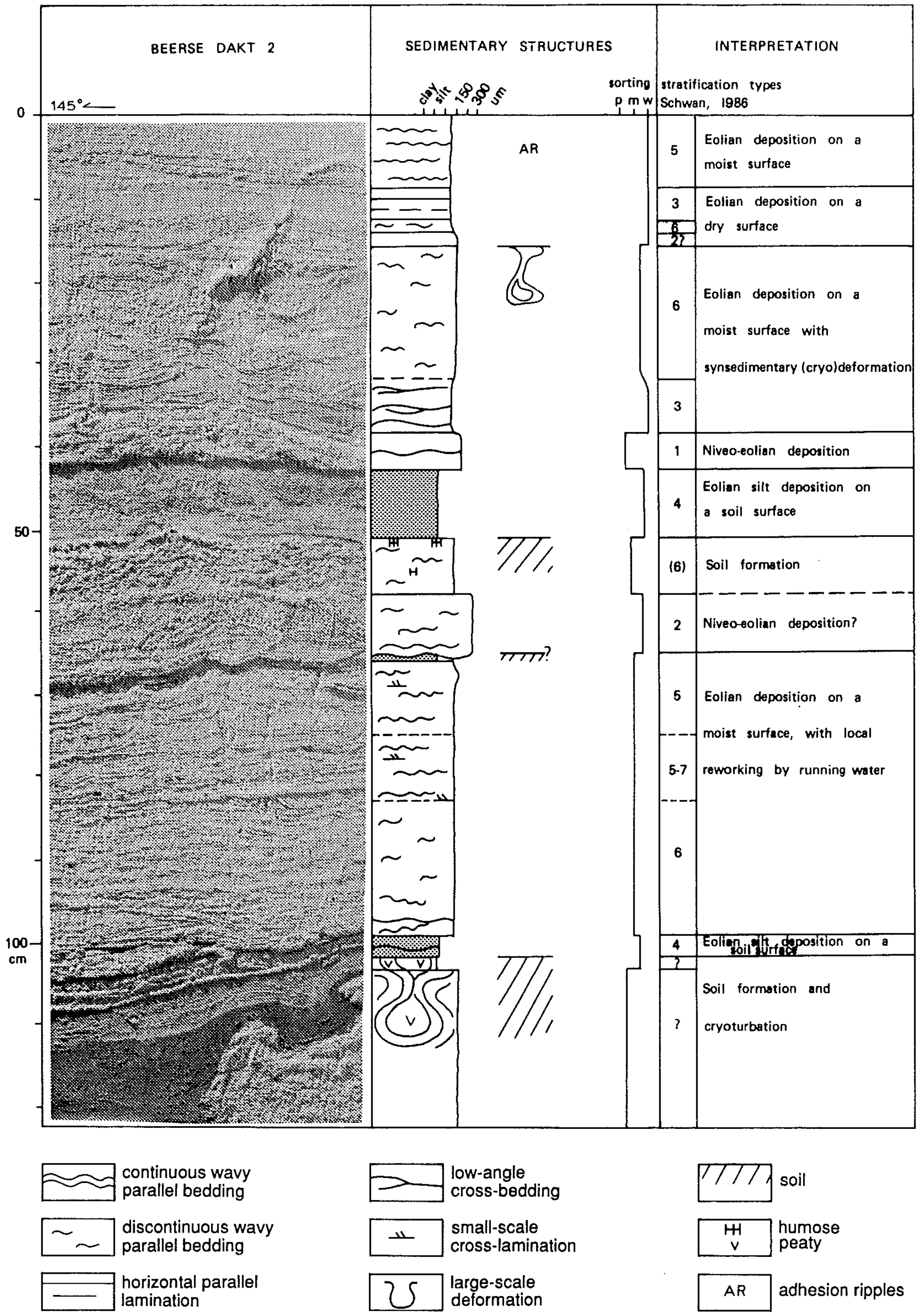


Fig. 8.4 Eolian and shallow fluvial periglacial sediments of the Beerse Member.

According to Schwan (1988) eolian sand sheet formation is favoured by:

1. Absence of large-scale topographic barriers that could stop the flow of sand. Although the regional paleomorphology during the formation of the Beerse Member is not known in great detail, it must have been a nearly flat surface, because deposition of the eolian sands occurred on the former estuarine plain of the Rijkevorsel Member.

2. Sparseness of the vegetation cover. However, Kocurek & Nielson (1986) stressed that the presence of a low vegetation is especially favourable for the development of warm-climate eolian sand sheets. Vegetation interferes with the free movement of sand, the migration of bedforms and the development of dunes with slipfaces.

Although vegetation was present during the formation of the humose soils and peaty beds (see section on vegetation), there are no sedimentological features (root-mottling, structureless beds) that point to the presence of vegetation during the deposition of the sand-units. The general wavyness of the bedding is attributed to eolian deposition on a moist to wet surface.

3. High ratio between wind energy and sand availability. A high ratio can be caused by the seasonally frozen state of the soil in winter and the thawed wet state in the summer, suppressing the sand availability for dune formation. A high water table will limit the amount of dry sand available for dune building as well (Kocurek & Nielson, 1986).

In the Beerse Member a high water table can be inferred from the presence of adhesion ripple lamination. The presence of small-scale current ripple cross-lamination points to periodic flooding of the depositional surface. The combination of a high water table and periodic flooding suppressed the dune formation and favoured the vertical accretion of the Beerse Member sand sheet.

Paleosols

The paleosols in the Beerse Member represent periods of non-deposition and surface stability in between the sand sheet accumulation phases. Peaty soils developed in the wet depressions and humose soils were formed on the higher locations (see fig. 8.2).

The peaty soils/beds have a brownish colour; the humose soils on the dryer sites have a light reddish to purplish gray colour (dry colour on lacquer peel: 5RP7/1 or 2.5YR7/1). The purplish gray topsoils (A-horizon) are somewhat bleached and impoverished in iron. The light gray to pale yellow subsoils are clearly mottled by iron (Cg-horizon). These gley features indicate periodic water saturation of the soil, which resulted in reduction and mobilization of the iron compounds. Subsequent oxidation during the dry season led to the precipitation of the iron compounds in iron oxides.

These A-Cg soils can be classified as Gleysols (FAO) or more precisely as Gelic Gleysol (FAO)/Pergelic Cryochrept (USDA) if permafrost was present (see below). The present-day Gelic Gleysols have an mean annual temperature below -1 °C and grasses, sedges, lichens and mosses are dominant in most plant communities (FitzPatrick, 1983). Where these recent soils grade into those of warmer areas trees become more important and the vegetation is characterized by conifers. Such plant communities are also induced from the pollen diagrams of the soils and peat-beds in the Beerse Member, which are dominated by pine, grasses, sedges and heather (see section vegetation).

The paleosols at Beerse are covered by silt-beds (fig. 8.4). These silt-beds are of eolian origin, since they have a massive structure and do not have any indication for a fluvial origin (no current ripples or channelling). They possibly formed at the start of a new sand sheet depositional phase, when the receiving site was not yet reached by the saltation sand carpet. At the same time suspension clouds of silt were generated in the source area during strong wind events. This silt settled from suspension during fair weather periods on the soils of the receiving site. This mechanism has been proposed previously by Schwan (1988) to explain the alternating bedding of silty and sandy beds in the northwest European Weichselian coversands. Later the migrating sand sheet reached the receiving site and eolian sand deposition became dominant over the continued, regional fall out of silt.

Periglacial structures

The Beerse Member is characterized by the presence of several types of periglacial structures (Kasse, 1988; Vandenberghe & Kasse, 1989). Frost cracks (50-70 cm deep) are found regularly below the deformed peaty soils. Small ice-wedge casts (c. 25 cm wide and 50 cm deep) occur infrequently. They may be regarded as initial ice-wedge casts which survived only a restricted timespan.

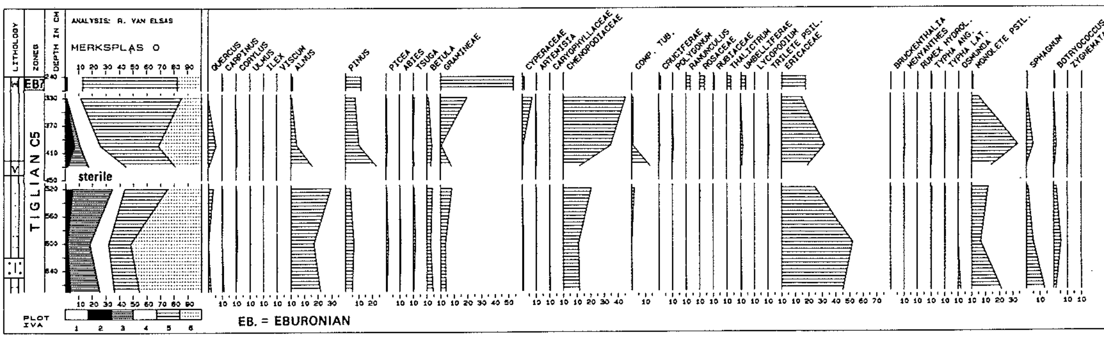
Large-scale deformations of the peaty beds are common. The peaty soils are often stronger deformed than the time equivalent humose soils probably because of the high soil moisture content at the time of disturbance. Degradation of local ground ice may have strengthened this loading effect, since more ground ice will have been formed in the low lying, wetter depressions.

The involutions are often regularly spaced and reach a maximal depth of 100 cm. These large deformations and small ice-wedge casts testify to the presence of a (local) permafrost. It means that the mean annual temperature was below -4 °C (Romanovskij, 1985). From this estimation it is concluded that the Beerse Member was formed in a cool to cold glacial period within the otherwise warm Tiglian stage.

Vegetation

The vegetation of the Beerse Member was studied by pollen analysis of the humose soils and peaty beds. The results are presented in fig. 8.5 (for location of the samples, see fig. 8.2).

Diagram Merksplas 5 (M 5) reveals a change in vegetation in the upper part of the Rijkevorsel clay. At the base of M5 thermophilous trees of dry (Quercus) and wet (Alnus) habitats are clearly present. The high Chenopodiaceae content (11%) illustrates the inshore tidal, estuarine depositional environment of the Rijkevorsel Member. The presence of Azolla tegeliensis in the Rijkevorsel Member (Greguss & Vanhoorne, 1961) points to a Tiglian age (Zagwijn, 1963). Kasse (1988) dated the top of the Rijkevorsel Member at the end of the warm temperate Tiglian C3 phase.


LITHOLOGY
ZONES
DEPTH IN CM
ANALYSIS: R. VAN ELSAS
MERKSPLAS 0
EB?
TIGLIAN C5
sterile
PLOT IVA
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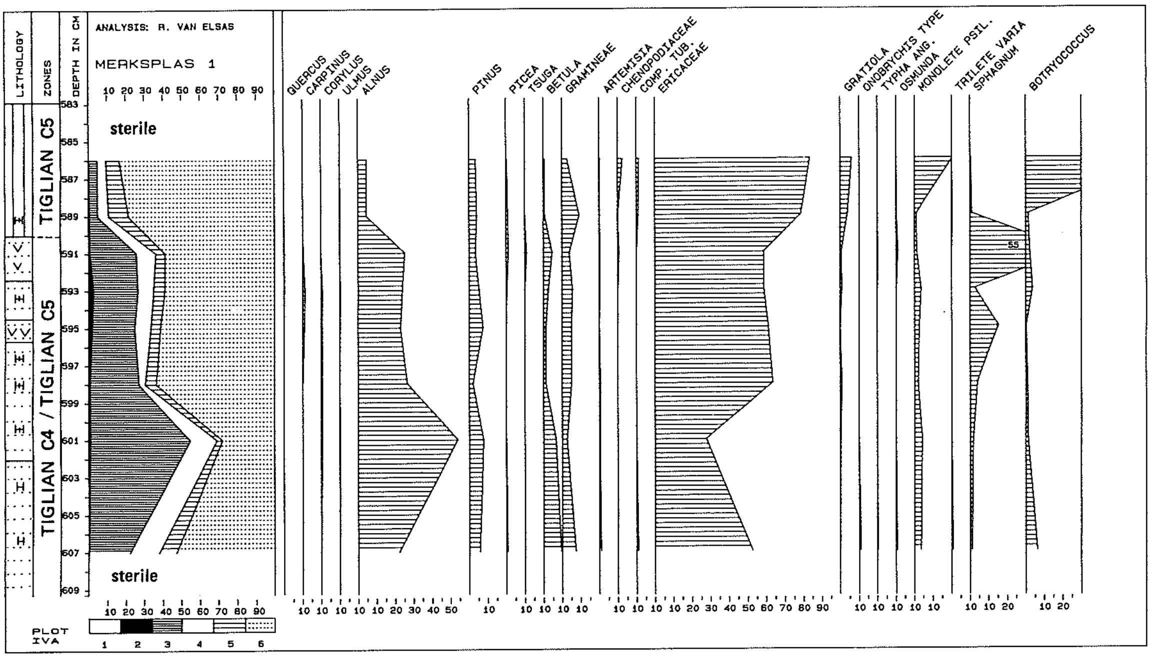
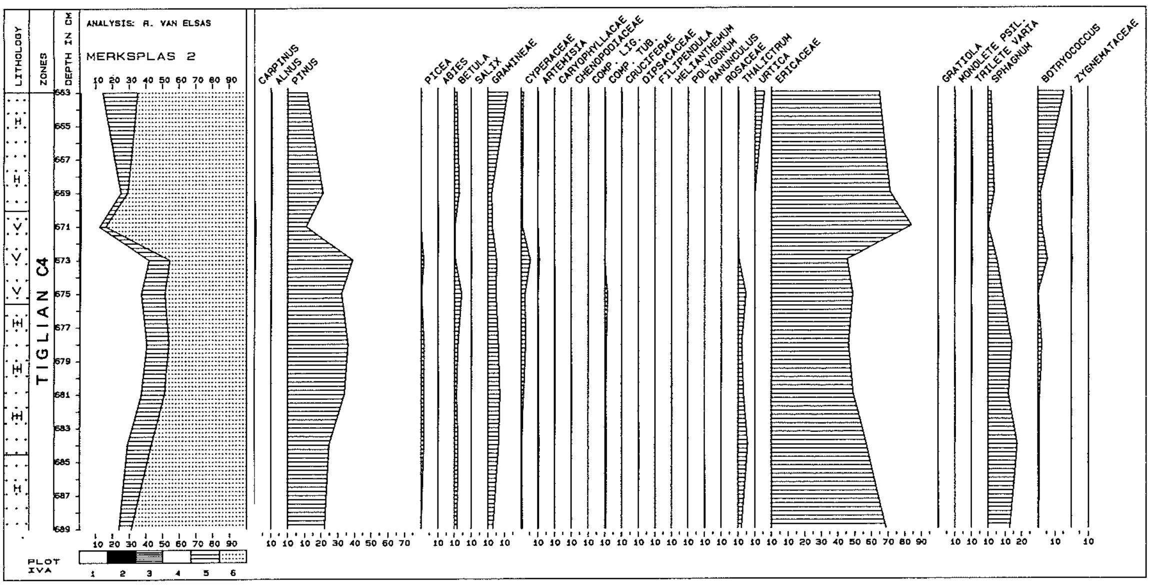
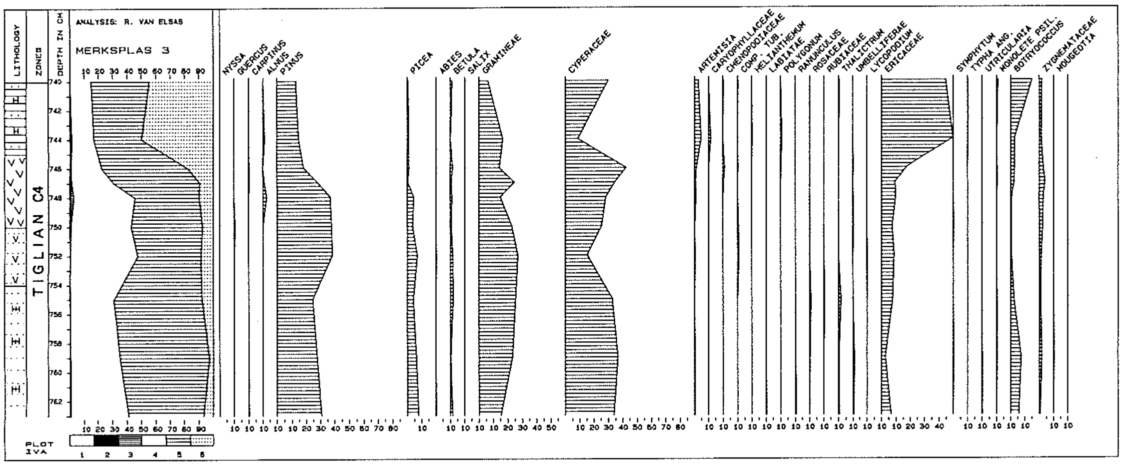
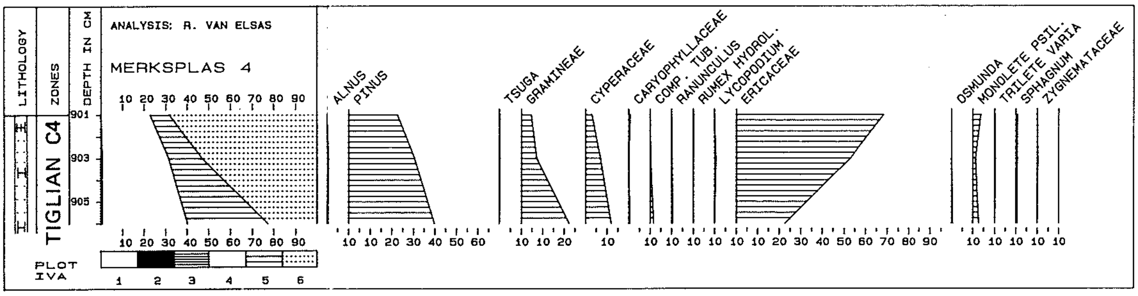

LITHOLOGY
ZONES
DEPTH IN CM
ANALYSIS: R. VAN ELSAS
MERKSPLAS 1
TIGLIAN C5
TIGLIAN C4 / TIGLIAN C5
sterile
QUERCUS
CARPINUS
CORYLUS
ULMUS
ALNUS
PINUS
PICEA
TSUGA
BETULA
GRAMINEAE
ARTEMISIA
CHENOPODIACEAE
COMP. TUB.
ERICACEAE
GRATIOLA
ONOBRYCHIS TYPE
TYPHA ANG.
OSMUNDA
MONOLETE PSIL.
TRILETE VARIA
SPHAGNUM
BOTRYOCOCCUS
55
PLOT IVA


LITHOLOGY
ZONES
DEPTH IN CM
ANALYSIS: R. VAN ELSAS
MERKSPLAS 2
TIGLIAN C4
CARPINUS
ALNUS
PINUS
PICEA
ABIES
BETULA
SALIX
GRAMINEAE
CYPERACEAE
ARTEMISIA
CARYOPHYLLACEAE
CHENOPODIACEAE
COMP. LIG.
COMP. TUB.
CRUCIFERAE
DIPSACACEAE
FILIPENDULA
HELIANTHEMUM
POLYGONUM
RANUNCULUS
ROSACEAE
THALICTRUM
URTICA
ERICACEAE
GRATIOLA
MONOLETE PSIL.
TRILETE VARIA
SPHAGNUM
BOTRYOCOCCUS
ZYGNEMATACEAE
PLOT IVA





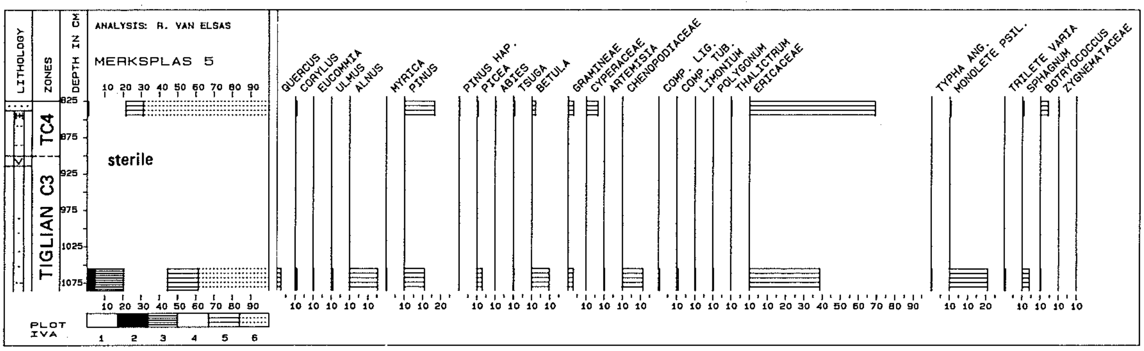


Fig. 8.5. Pollen diagrams of the Rijkevorsel (Tiglian C3), Beerse (Tiglian C4) and Turnhout Member (Tiglian C5) at Merksplas. Legend of main diagram: 1=Tertiary trees; 2=thermophilous trees (dry); 3=thermophilous trees (wet); 4=other trees; 5=terrestrial herbs; 6=Ericales.

The top of the Rijkevorsel Member (fig. 8.5: top diagram Merksplas 5 and Merksplas 4) reveals a completely different vegetation type. Thermophilous trees are absent and the pollen spectrum is dominated by Pinus, Gramineae, Cyperaceae and Ericaceae. This pollen assemblage resembles a boreal coniferous forest vegetation.

Unfortunately, the transition of the warm temperate forest vegetation of the Tiglian C3 period into the cool/cold boreal vegetation of the Tiglian C4 is missing. This interval is sterile in pollen, probably because of oxidation and soil ripening during the final silting of the Rijkevorsel Member.

Like in the top of the Rijkevorsel Member, the soils within the Beerse Member are characterized by Pinus, Gramineae, Cyperaceae and Ericaceae (fig. 8.5: Merksplas 3 and 2). The differences in pollen composition in Merksplas 2 and 3 are caused by local factors and local dominance of species. The peat-bed of Merksplas 3 was formed in a wet environment and therefore, the diagram is dominated by species of wet habitats (Gramineae and Cyperaceae). The soil of Merksplas 2 on the other hand developed under dryer conditions, which is reflected by higher values of Ericaceae.

The increase of Artemisia in the top of Merksplas 3 and Thalictrum in Merksplas 2 possibly indicate a change to a more continental climate during the formation of the upper part of the Beerse Member.

The soil at the top of the Beerse Member shows a different pollen composition (fig. 8.5: Merksplas 1). It is characterized by Alnus and Ericaceae. The Alnus increase possibly represents the climatological change from the cool/cold Tiglian C4 into the warm temperate Tiglian C5. The boreal coniferous forest (Merksplas 2, 3, 4) was succeeded by a deciduous forest (Merksplas 1 and 0). It is supposed that soil Merksplas 1 represents an interglacial soil, which was formed before the marine transgression inundated the area in the course of the Tiglian C5. This marine transgression, caused by post-glacial sea level rise, truncated the top of soil 1, and deposited a 4-5 m thick clay-unit in the excursion area (Turnhout Member). Like in the Rijkevorsel Member, the pollen composition of the Turnhout Member is characterized by thermophilous trees of dry and wet habitats (up to 30% in fig. 8.5: Merksplas 0), which points to deposition in a warm temperate climate. The estuarine nature of the clay-unit is clear by the strong dominance of Chenopodiaceae (up to 40%). The presence of Azolla tegeliensis in the macro remains of Merksplas 0 at 5.2 m proves the Tiglian age of the Turnhout Member. Kasse (1988) related the Turnhout Member more precisely to the Tiglian C5 phase.

<u>Climatic evolution during the Late Tiglian</u>

Paleobotanical information and periglacial phenomena have been used to reconstruct the mean annual and mean July temperature curves of the Early-Pleistocene (Zagwijn, 1963; Vandenberghe & Kasse, 1989). The climatological results are summarized in table 1.3.1.

The pollen of Ilex and Hedera in the Rijkevorsel and Turnhout Members indicates mild winter conditions with mean temperatures above 0 °C during the interglacial Tiglian C3 and C5. Hedera, Vitis and Eucommia are connected to a mean summer temperature between 16 and 20 °C.

The abundance of Pinus, Gramineae, Cyperaceae and Ericaceae in the soils of the Beerse Member points to an open pine forest vegetation. From this a mean summer temperature can be inferred of about 10 °C. This implies a summer temperature drop of almost 10 °C at the transition from the Tiglian C3 to the Tiglian C4.

The initial ice-wedge casts and large cryoturbations in the Beerse Member allow an estimation of the mean annual temperature of maximal -4 °C. These temperature estimations reveal that the mean annual temperature of the Early-Pleistocene Beerse Glacial is comparable to those of the Late-Pleistocene (Kasse, 1988).

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